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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MAGNESIUM-BEARING MINERALS IN THE BOULDER DAM AREA FOR THE PRODUCTION OF MAGNESIUM METAL[1]

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INTRODUCTION

The present emergency has greatly stimulated interest in the light metals - aluminum and magnesium - owing to their extensive use in airplane construction. The $63,000,000 plant being erected in the Las Vegas Valley by Basic Magnesium, Inc., under the auspices of the Defense Plant Corporation, for the purpose of augmenting production of magnesium from domestic ores in the Boulder Dam area has greatly increased local interest in magnesium-bearing minerals.

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[1] The Bureau of Mines will welcome reprinting of this report, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7216."

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For several years preceding the present emergency the entire commercial output of metallic magnesium in the United States resulted from the refining of natural brines or sea water. The magnesium chloride in these brines was obtained as a byproduct from other chemical industries and was a cheaper source of magnesium than magnesium-bearing ores.

A number of the more recently proposed processes for magnesium production require magnesium oxide as a raw material. The purpose of this paper is (1) to summarize the known ore deposits in the Boulder Dam area that might be used as a source of the required magnesium oxide and (2) to clarify the question as to which type of deposit has potential value for the production of magnesium metal. The Boulder Dam area is defined, according to Geological Survey Bull. 871, as that area within a radius of 200 miles from the dam.

Magnesium rock samples received at the Boulder City station for identification and appraisal of their possible use as a source of magnesium have been classified as follows:

1. High-grade magnesite.
2. Low-grade magnesite.
3. Dolomite.

Brucite and magnesium-bearing brines have not been included, since only very limited occurrences have been reported in the immediate vicinity.

HIGH-GRADE MAGNESITE

The term "high-grade magnesite," for the purpose of this paper, refers to a material of such purity that it can be used without chemical treatment for either chlorination or direct electrolytic reduction processes. Ore dressing and calcination are not classed as chemical treatments. Calcium and silicon are the critical impurities in the magnesium oxide to be chlorinated for use at the plant in the Las Vegas Valley. Nearly all magnesites contain the oxides of iron and aluminum, but for this particular process they are less serious impurities than calcium or silicon. During chlorination, the iron oxides, alumina, and part of the silica are chlorinated and volatilized. The silica reaction products accumulate in the scrubbers and other auxiliary

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apparatus, necessitating periodic shut downs to remove them. All impurities consume valuable chlorine, which is not recovered. Serious accumulation of calcium in the molten electrolytic bath is prevented by periodically removing some of the molten salt and discarding it. Thus, the exact amount of allowable impurities in the raw ore is a matter of economics, and while pure magnesium oxide is a more desirable raw material, it must be relatively low-priced to compete with an abundant supply of cheap, lower-grade material.

Magnesite of this required quality has not been reported in quantity in the Boulder Dam area. However, magnesites containing 2 to 5 percent calcium oxide are described in the section on low-grade magnesite deposits. The magnesium plant in the Las Vegas Valley is expected to use crude magnesium oxide obtained from magnesite mined from the west slope of the Paradise Range, Nye County, Nev., 325 miles by road from Las Vegas. This magnesite is gray to black and coarsely crystalline-granular, and has an average specific gravity of 3.0.

LOW-GRADE MAGNESITE

A low-grade magnesite, as referred to in this paper, is one that cannot be economically used directly for magnesium production by electrolysis or by chlorination and electrolysis of the chloride, but which can be treated by relatively simple chemical means to produce pure magnesium oxide. Magnesites containing over 30 percent magnesium oxide, or carbonate rocks resembling magnesite and made up of magnesite, dolomite, calcite, and other magnesium-bearing minerals soluble in hot, dilute hydrochloric acid, are included in this group. Successful use of low-grade magnesite for production of magnesium depends only on the development of an economical method of recovering the contained magnesium oxide.

The best grade of magnesite found in the Las Vegas area contains 2 to 5 percent calcium oxide. It is chalky-white, exceedingly fine-grained, crystalline, and compact in testure, and its fracture is splintery, conchoidal, or shell-like. With greater clay and iron content the color may be white, light or dark gray, or pink; the texture is less compact than that of purer material. It is not as hard and the fracture is not as smooth and porcelain like as the purer material.

For purposes of field identification, the average prospector looking for magnesite is informed that it usually occurs as a chalky-white, fine-grained rock that breaks with a conchoidal fracture. However, this description fits dolomite, limestone, and other rock types from the Las Vegas area. Some of the rocks and minerals sent to the laboratory as magnesite have been identified as clay, calcite, dolomite, calcareous shale, fine-grained calcareous clayey sandstone, altered feldspars, rhyolite tuff, diatomaceous earth, tremolite, quartzite, silicified rhyolite, gypsum, chert, opal, and meerschaum.

Familiarity with the properties of magnesite and other rocks and their field occurrences will eliminate all but dolomite from the rock types and minerals that can be mistaken for magnesite. The Mohs scale hardness of magnesite is 3.5 to 4.5; it can be scratched with a knife blade with moderate difficulty. The specific gravity is 3.1; therefore, it is heavier than quartz (sp. gr. 2.6) and lighter than barite (sp. gr. 4.3 to 4.6). Effervescenc following application of a drop of cold, dilute (1:1) hydrochloric acid to a freshly broken surface is an entirely reliable indication of the presence of calcite. The more vigorous the action, the greater the amount of calcite present. Magnesite and dolomite do not effervesce with this reagent. Clay is indicated by a clayey odor when the rock is moistened.

OCCURRENCES

Magnesite deposits occur in three principal forms: (1) As nonmarine sedimentary beds interstratified with dolomite, clay, and other detrital materials; (2) as massive, fine or coarsegrained, crystalline deposits formed by replacement of dolomite or calcite with magnesium-bearing solutions; and (3) as irregular veins and pockets in serpentine bodies. Only the first two types have been reported in the Las Vegas area.

Sedimentary Magnesite

Sedimentary deposits in this area were formed in small, isolated, continental basins during the Tertiary period.[3] Longwell[4] suggests that they were deposited as sediments in a playa lake and that the magnesium was brought into the lake by hot springs of deep-seated origin. Some of the known sedimentary deposits in the Boulder Dam area are potential sources of magnesium oxide for use in magnesium-metal production. The following deposits are important examples of this type in the area.

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[3] The Overton magnesite may be upper cretaceous in part (see Rubey, W. W., and Callaghan, Eugene, Mineral Resources of the Region Around Boulder Dam: Geol. Survey Bull. 871, 1936, pp. 121-122).

[4] Longwell, C. R., Geology of the Muddy Mountains: Geol. Survey Bull. 798, 1928, pp. 82-85.

Bissell, Calif.

Rubey and Callaghan[5] state:

> Bedded magnesite occurs on the south slope of a low ridge in the northeastern part of sec. 11, T. 10 N., R. 11 W. (San Bernardino Base and Meridian), slightly less than a mile northeast of Bissell station on the Atchison, Topeka & Santa Fe Railway and 10.3 miles by road east of Mojave. The magnesite occurs as a group of thin white beds (mostly less than one foot thick), with dark, silty, clay interbeds in a thick series of sediments regarded as of middle Miocene age. The magnesite zone ranges in thickness from a few feet to as much as 75 feet***. Not only are there irregularities in the strike of the formation as a whole, and possibly some minor faults, but the soft magnesite and associated clays are in places greatly contorted and broken, in much the same way as some of the beds in the deposits near Overton, Nev.

The deposit was worked from 1915 to 1923, and total production was 15,757 tons.

The analyses in table 1 were taken from Rubey and Callaghan, who were quoting Gale.[6] They were made by J. G. Fairchild in the Geological Survey laboratory.

TABLE 1. - Analyses of magnesite from deposits near Bissell, Calif.

SiO_2	9.64	4.75
$Al_2O_3 + Fe_2O_3$	2.46	.76
MgO	37.19	44.20
CaO	4.25	Trace
CO_2	40.70	47.32
Undetermined	5.76	2.97

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[5] Rubey, W. W., and Callaghan, Eugene, Mineral Resources of the Region Around Boulder Dam: Geol. Survey Bull. 871, 1936, pp. 114-117.

[6] Gale, H. S., Newly Discovered Deposits at Bissell Station, near Mojave, Calif.: Geol. Survey, Mineral Resources, 1911, pt. 2, pp. 1115-1120, 1912; Late Developments of Magnesite Deposits in California and Nevada: Geol. Survey Bull. 540, 1914, pp. 512-516.

On the basis of a rock density of 2.2 and an aggregate thickness of workable magnesite of 5 feet for a depth of 100 feet down the dip, the estimated reserves would be about 100,000 tons. Probably a much larger amount might be recovered.[7]

Afton, Calif.

A deposit of bedded magnesite occurs on the south side of Cave Canyon of the Mojave River, 1-1/2 miles southeast of Afton, 3-1/2 miles west of Baxter, and about 2,000 feet from the tracks of the Union Pacific Railroad. White and pink fine-grained carbonate rock of variable thickness, but largely from 30 to 40 feet, crops out for a horizontal distance of 400 to 500 feet in the rugged canyon wall that rises about 500 feet above the bed of the river. The carbonate rock appears to be near the base of a folded and faulted series of rocks of probable Tertiary age and dips steeply north.*** . Underground mining would be necessary to extract most of the deposit.[8]

The analyses in table 2 are from Rubey and Callaghan (p. 118).

TABLE 2. - Analyses of magnesite from deposit near Afton, Calif.

	AM1	AM2	AM4	AM6
Insoluble in 1/4 HCl	12.2	7.3	17.5	16.6
MgO....................	20.6	35.6	30.9	33.5
CaO	24.4	7.8	6.6	4.7

AM1 - Tough, pinkish, carbonate rock 3.5 feet thick at south end of old quarry face.

AM2 - Hard, white, carbonate rock 1.0 foot thick above AM1.

AM4 - Moderately hard, white, carbonate rock 3.0 feet thick at north end of old quarry face.

AM6 - Hard, white, carbonate rock 2.8 feet thick above AM4.

Regarding the reserves, Rubey and Callaghan say (p. 118):

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[7] Rubey, W. W., and Callaghan, Eugene, Mineral Resources of the Region Around Boulder Dam: Geol. Survey Bull. 871, 1936, p. 117.

[8] Rubey, W. W., and Callaghan, Eugene, Work cited in footnote 7, pp. 117-11

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At an estimated average thickness of about 13 feet of magnesite, it appears that there is above the level of the canyon floor between 100,000 and 200,000 tons of ore with an MgO content of 30 percent or more.

Overton, Nev.

Sedimentary magnesite is exposed in the walls of two washes 1 mile apart and about 5 miles south-southwest of Overton and 3 miles southwest of the Union Pacific Railroad. The magnesite occurs in a carbonate member (white magnesite and dolomite beds) of the Horse Springs formation, which is classified tentatively by Rubey and Callaghan as Tertiary (Miocene ?) in age. The carbonate member is 155 to 325 feet thick and lies between two silstone units, all dipping 25° to 40° N.E. away from the Muddy Mountain complex of folded and faulted sedimentary rocks of Cambrian to Jurassic (?) age.

> The carbonate member of the Horse Springs formation*** consists chiefly of glaringly white, thinly laminated, rather claylike rocks. These white carbonate rocks are faintly tinged with pale-gray, pinkish, and greenish tints, and thin layers of green and red clay and thicker beds of red silstone recur throughout the member. It is extremely difficult to distinguish the more magnesitic from the more dolomitic and clayey layers, but in general the purer magnesite layers are whiter and more massive and tend to break with a more conchoidal fracture. Both carbonates and clays are exceedingly fine-grained, and in their general appearance they resemble dense, white, flint clay rather than ordinary carbonates.[9]

Detailed measurements and chemical analyses of the carbonate unit were made by Rubey and Callaghan and are published in Geological Survey Bulletin 871, pp. 122-136.

TABLE 3. - Chemical analyses of Overton magnesite deposit

	M6	BM 20,031	18A
Insoluble in 1/4 HCl	11.33	12.38	14.6
MgO	36.14	37.96	34.1
CaO	6.24	5.58	7.3
R_2O_3	1.48	1.19	

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[9] Rubey, W. W., and Callaghan, Eugene, Work cited in footnote 7, p. 122.

M6 - Channel sample represents 7.2 feet of white massive carbonate on south side of magnesite wash. (Quoted from Rubey and Callaghan.)

BM20,031 - Sample from most magnesitic-appearing beds in zone 50 feet wide on north side of magnesite wash. (Collected by Bureau of Mines.)

18A - Zone of magnesitic carbonate 6 feet thick, 39 feet above base of carbonate member in kaolin wash. (From Rubey and Callaghan.)

The following estimate of reserves "of the total tonnage of magnesite above entry level and virtually in sight" is given by Rubey and Callaghan:

TABLE 4. - Estimated tonnage of magnesite in overton area

Minimum grade of ore	Magnesite (short tons)			
MgO, percent	In beds 4 feet or more thick	In beds 2 feet or more thick	In beds 1 foot or more thick	In beds 6 inches or more thick
38	290,000	430,000	760,000	850,000
34	3,100,000	3,500,000	3,600,000	3,700,000
30	4,500,000	4,900,000	5,000,000	5,100,000

Bauer Deposit Near Overton, Nev.[10]

A soft, white, carbonate unit of the Horse Springs formation 35 to 80 feet thick, consisting of dolomite and magnesite, outcrops for 3,500 feet along the strike about 9 miles due north of the former post office of Gold Butte. The deposits dip 25° to 30° ESE.

TABLE 5. - Analyses of samples from Bauer magnesite deposit

	B4[1]	B5[1]	BM 2465	BM 2489
MgO	41.3	38.4	40.63	41.14
CaO.....................	3.1	8.5	3.45	
Insoluble in 1/4 HCl	6.2	4.0	2.22	4.1

[1] Taken from Rubey and Callaghan, p. 141.

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[10] Description taken from Rubey, W. W., and Callaghan, Eugene, Work cited in footnote 7, p. 140.

B4 - Hard, white bed, 0.4 foot thick, just inside the portal of southern tunnel.

B5 - Hard, white bed, 4.5 feet thick, exposed at surface 35 feet north of southern tunnel.

BM2465 - Hand-sorted sample taken by Albert Bauer from surface. (Analysis by Bureau of Mines.)

BM2489 - Hand-sorted sample taken by Albert Bauer from surface. (Analysis by Bureau of Mines.)

In estimating the reserves, Rubey and Callaghan say (p. 141):

> The total thickness of magnesite in this deposit is not known, but if it averages 20 feet the material above entry level amounts to about 500,000 tons.

Needles, Calif.

Magnesite occurs in the hills 13 miles southwest of Needles, Calif., in the S. 1/2, sec. 15, and N. 1/2, sec. 22, T. 8 N., R. 21 E., San Bernardino Base and Meridian. The deposit is tentatively grouped with the sedimentary magnesites, although only a cursory field examination was made, which did not reveal the stratigraphic position and age of the beds. Beds of thick, gray dolomite and limestone carrying abundant, irregular chert masses are exposed in masses 15 to 20 feet thick in the topographically higher parts of the deposit. The magnesite lies below the cherty dolomite and limestone beds, separated from them by a section of white, thin-bedded limestone and dolomite 2 to 4 feet thick. The magnesite weathers whiter than the overlying thin-bedded carbonate and fractures with an uneven to rough surface. Evidence of shearing and movement in the magnesite is shown by numerous shiny, slickensided surfaces and the almost complete obliteration of bedding planes.

The cherty limestone and dolomite resemble fossiliferous Paleozoic sediments exposed in adjacent areas in California, Arizona, and Nevada. Unfortunately, the nature of the contact and, hence, the relative ages of these beds and the underlying, white, thin-bedded carbonate starta and magnesite have not yet been determined. An irregular, dikelike body of an apparently acid, volcanic or hypabyssal rock traverses the magnesite deposit on the surface.

Numerous cuts and trenches dug in all parts of the deposit expose the magnesite. Trenches expose a vertical 8 to 10 feet of magnesite below the limestone and dolomite beds in the hill in the northwestern part of the deposit with the floor of the trenches still in magnesite. In the lower, flatter, southeastern part cherty limestone and dolomite beds are missing, and white carbonates form the surface debris. According to J. Lex Brown, one of the owners, diamond drilling failed to reach the bottom of the deposit at a depth of 62 feet in its northwestern half and 50 feet in its southeastern half. The surface outcrop is approximately 500 feet wide and 1,500 feet long.

Table 6 contains chemical analyses of various samples taken from the magnesite deposit at Needles, Calif.

TABLE 6. - Analyses of magnesite from Needles, Calif.

	1	2	BM2472	BM20071
MgO	45.32	44.24	44.2	45.77
CaO	.82		.75	4.12
SiO_2	3.02			
Al_2O_3 and Fe_2O_3				.35
Insoluble 1/4 N acid			8.39	2.02

1 - Taken by Max C. King, consulting engineer, "Ore samples were cut from the series of tunnels, cuts, and open pits.***. A carefully prepared general sample was submitted for analysis."

2 - Said to have been taken from surface and analyzed by Smith, Emery & Co. Los Angeles.

BM2472 - 25-pound piece of magnesite submitted to Bureau of Mines for analysis by J. Lex Brown.

BM20071 - 200-pound sample collected from "all parts of the deposit" by J. Lex Brown and analyzed by the Bureau of Mines.

MASSIVE REPLACEMENT MAGNESITE

Many square miles in the Las Vegas area expose vast deposits of Paleozoic dolomite and limestone. Igneous intrusion in local areas in these Paleozoic sediments has caused metamorphism and replacement of the originall

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deposited minerals. Longwell[11], indeed, suggests that the magnesium in the dolomite of the Paleozoic formations in the Muddy Mountain region was derived from the same deep-seated, igneous source that furnished the magnesium for the body of water from which the Overton magnesite was deposited.

A well-known example of this type is the "Luning magnesite" from the west slope of the Paradise Range, Nye County, Nev., 33 miles by road northeast of Luning, Nev. Here magnesite ($MgCO_3$), hydromagnesite ($3MgCO_3 \cdot Mg(OH)_2 \cdot 3H_2O$), and brucite ($Mg(OH)_2$) deposits of very irregular shape and distribution have been formed by the alteration of limestone or dolomite by heat and fluids given off during the intrusion of an igneous rock magma. The actual mechanism of change from limestone or dolomite to magnesite, hydromagnesite, and brucite depends on the nature and composition of the materials derived from the deep-seated source and the physicochemical relationships existing during the period of intrusion. An example of a simple, theoretically possible mechanism for a change of dolomite to brucite (that does not depend on the introduction of magnesium from a deep-seated source) is governed by the principle of the lesser stability of the magnesium than of the calcic component upon heating dolomite under low pressures:[12]

$$\underset{\text{(dolomite)}}{CaMg(CO_3)_2} \longrightarrow \underset{\text{(calcite)}}{CaCO_3} + \underset{\text{(periclase)}}{MgO} + CO_2.$$

Periclase will hydrate readily to form brucite:

$$\underset{\text{(periclase)}}{MgO} + \underset{\text{(water)}}{H_2O} \longrightarrow \underset{\text{(brucite)}}{Mg(OH)_2}.$$

Such conditions may exist in the vicinity of stocklike, igneous, intrusive bodies in limestone or dolomite during or immediately after the period of emplacement. Gaseous and liquid emanations carrying chemically active substances from the magma soak into the invaded rock and start chemical changes far more complex than those caused by heat alone.[13]

At Luning, Nev., according to the mapping of Callaghan, a granodiorite body of Upper Jurassic (?) age had intruded a succession of Upper Triassic dolomite sediments, producing hydromagnesite, brucite, magnesite, and hydrothermally altered dolomite. Numerous dikes, sills, and lenses of igneous rock cut the dolomite and its metamorphos equivalents and the granodiorite body itself.[14] Rubey and Callaghan[15] state:

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[11] Longwell, C. R., Work cited in footnote 4, p. 85.

[12] Tyrrell, G. W., The Principles of Petrology, 1926, p. 298.

[13] Bain, G. W., Types of Magnesite Deposits and Their Origin: Econ. Geol., vol. 19, pp. 424-429.

[14] See plate 13, Geol. Survey Bull. 871, 1936 (cited in footnote 7).

[15] Work cited in footnote 7, pp. 142-143.

Reserves of brucite to a depth of 350 feet in the upper or eastern deposit are estimated at 3,000,000 tons. A similar estimate for the lower deposit to a depth of 100 feet below the hydromagnesite blanket is 348,000 tons. ***. A total area of magnesite represented on the map is about 136 acres, which to a depth of 100 feet would contain about 55,000,000 tons. ***. Depths of 200 or 300 feet for the larger masses are not unreasonable and might very well double the figure given. ***. An additional 16,000,000 tons may be available*** (outside the area mapped by Callaghan).

Partial analyses B and C below were made of magnesite near the brucite deposit in the laboratory of Abbot A. Hanks, Inc. Complete analysis A was made by E. Y. Erickson, of the Geological Survey.

TABLE 5. - Analyses of Luning magnesite

	A	B	C	BM20030
SiO_2	0.43	1.81	1.38	1.21
Al_2O_3	.13	.62	.50	.82
Fe_2O_3	.23	.57	.47	.82
MgO	45.35	46.85	45.58	47.40
CaO	2.20	1.46	1.85	1.20
H_2O	.11			
CO2	51.03			
P_2O_5	.03			
TiO_2	Trace			
FeO	.22			
MnO	.02			
S	.03			
Carbonaceous matter	Trace			
	99.78			

A - Specimen from small body of magnesite in dolomite southeast of the tungsten workings.

B - Average of 36 feet of core, hole 27, near upper deposit. (Taken from Rubey, W. W., and Callaghan, Eugene, Work cited in footnote 7, p. 143.)

C - Average of 12 analyses of 210 feet of core, hole 16, upper deposit. (Taken from Rubey and Callaghan, Work cited in footnote 7, p. 143.

BM20030 - Quartered sample of 5-ton lot of high-grade, hand-sorted material obtained by the Bureau of Mines from Basic Ores, Inc., of Luning, Nev. Analyzed by P. R. Perry, associate chemist, Bureau of Mines, Boulder City (Nev.) Experiment Station.

Cima, Calif.

A small deposit of magnesite occurs 12 miles northeast of Cima, a station on the Union Pacific Railroad.***. According to Hewett, who examined this deposit in 1929, the magnesite occurs as a well-defined layer 1 to 3 feet thick between good walls in Paleozoic dolomites.[16]

The magnesite follows a fracture that crosses the dolomite at a low angle. Reserves probably are small.

Indian Springs, Nev.

A small replacement deposit of magnesite in dolomite is found 18 miles northwest of Indian Springs, Nev. The deposit is 1 mile east of the Oak Springs road, 12.5 miles from State Highway 5. Hard, snow-white, compact to fine-grained, crystalline magnesite replaces bedded dolomite dipping 15° due north and forming a flat, visibly outcropping body about 90 feet long, 40 feet wide, and 5 to 6 feet thick. Below the magnesite is a transition zone about 1 foot thick made up of 1/4-inch, rounded masses of white magnesite in a matrix of light-gray cellular dolomite.

TABLE 7. - Analyses of Indian Springs magnesite

	BM20005	BM2413	BM2513
SiO_2		0.5	
MgO	45.26	46.2	44.16
CaO	6.02		2.60

BM20005 - Average of 300-pound sample of high-grade, hand-sorted material.

BM2413 - Lump sample of high-grade material collected by John Lytle.

BM2513 - Lump sample of high-grade material collected by F. F. Garside.

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[16] Rubey, W. W., and Callaghan, Eugene, Work cited in footnote 7.

OTHER REPORTED OCCURRENCES

Numerous small replacement bodies of magnesite, hydromagnesite, and brucitic dolomite occur near Cima, Goodsprings, Paradise Range, and probably other districts in the vast areas exposing dolomite and limestone sediments. The deposits are commonly close to igneous intrusive contacts and are usually localized along faults. (Oral communication from H. C. Lee, technical advisor for Basic Magnesium, Inc.)

DOLOMITES

True dolomite is an equimolecular combination of calcium and magnesium carbonates, but the term often is applied to any rock in which these carbonates are present in nearly equal amounts. When pure, dolomite contains 21.8 percent magnesium oxide and 30.4 percent calcium oxide. This material represents an almost inexhaustible source of magnesium metal, and the vast deposits of sedimentary dolomite in this immediate area constitute a challenge and an opportunity to the magnesium metallurgist.

The Bureau of Mines has made preliminary experiments and estimated costs on several processes for treating high-grade Nevada dolomites, such as the Sloan dolomite tabulated in table 8, to obtain pure magnesium oxide. These investigations will be reported in a future publication of the Bureau of Mines.

Dolomite occurs chiefly as a crystalline sedimentary rock.

Properties

Dolomite may be white, reddish- or greenish-white, red, gray, or black. Dolomite crystals resemble calcite crystals; however, the rhombic cleavage faces generally are curved. Its streak is always white, light gray, or colorless. It is harder than calcite and softer than fluorite, and can be scratched with a steel blade. Having a specific gravity of 2.8 to 2.9, it is slightly heavier than calcite (sp. gr. 2.7). It can readily be distinguished from calcite by testing with cold, dilute (1:1) hydrochloric acid. The mineral to be tested is separated from the associated minerals, and a drop of the acid reagent is applied. Calcite will effervesce freely; dolomite, like magnesite, will not effervesce.

Occurrences

All publications on the geology of selected districts in the Las Vegas area mention dolomite as an important rock type.[17]

In summarizing the occurrences of limestone and dolomite in this area, B. N. Moore writes:[18]

> The Boulder Dam region is assured of a large supply of excellent limestones and dolomites. The mountains that lie on both sides of the Union Pacific Railroad from Nipton north nearly to Moapa, a distance of about 100 miles, are made up largely of limestone and dolomite. The reserves of these rocks in the region are therefore very large***.

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[17] Hewett, D. F., Geology and Ore Deposits of the Goodsprings Quadrangle, Nev.: Geol. Survey Prof. Paper 162, 1931, 172 pp.
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Noble, L. F., Rock Formations of Death Valley, California: Science, new series, vol. 80, 1934, pp. 173-178.

[18] Mineral Resources of the Region Around Boulder Dam, Geol. Survey Bull. 871, 1936, p. 165.

D. F. Hewett has mapped approximately 32 square miles of area exposing the Goodsprings dolomite of Cambrian to Devonian (?) age in the Goodsprings Quadrangle. This formation is composed dominantly of dolomite and dolomitic limestone of 2,500 feet maximum thickness. Other Paleozoic formations in this area contain prominent dolomite members and cover many square miles. These formations continue far beyond the boundaries of the Goodsprings Quadrangle. Eleven miles east of the eastern boundary of the quandrangel, at Sloan, Nev., a 600-foot-thick, flat-lying bed of Devonian dolomite of a high degree of purity is being worked by the United States Lime Products Corporation and is yielding 1,500 tons a month at present.

TABLE 8. - Analyses of Sloan dolomite[19]

Acid insoluble	0.21
Fe_2O_3 Al_2O_3	.44
CaO	30.05
MgO	21.80
Ignition loss	47.50
	100.00

[19] Carpenter, J. A., Mineral Resources of Southern Nevada: Nevada State Bur. Mines Bull., vol. 1, No. 1, 1929, p. 10.

CONCLUSION

The magnesium-containing deposits included in this publication should not be considered an all-inclusive list of deposits or minerals occurring in the Boulder Dam area that might become a source of raw material for a magnesium metal industry. However, some of the deposits discussed in this report are rather extensive and relatively well-known and represent an almost unlimited source of magnesium metal. Utilization of this source of raw material depends principally on the cost of extracting the metal from it as compared to the cost of recovery from higher-grade ores or saline brines.